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CONTENTS

REFLECTIONS ON FORTY YEARS INDUSTRIAL RESEARCH 53
By B. P. Dudding

NOTICES TO MEMBERS - - - - - - - 55
Bournemouth Convention ; Salary Enquiry ; Monographs for Students ; List of Members ; Institute Publications ; Summer Meetings

RESEARCH ASSOCIATIONS - - - - - - - 56
I—The Electrical Research Association
By S. Whitehead

PHYSICS IN TECHNICAL COLLEGES - - - - - 61
III—The College of Technology, Birmingham
By M. R. Gavin

REVIEWS OF BOOKS - - - - - - - 63

THE REGISTER - - - - - - - - 65

COURSES : APPOINTMENTS VACANT - - - - 67

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## REFLECTIONS ON FORTY YEARS INDUSTRIAL RESEARCH

By B. P. DUDDING, M.B.E., Ph.D., F.Inst.P.
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[*This article consists of extracts from an address given to the Union Scientifique Continentale du Verre on December 4, 1952, in Charleroi, Belgium. Dr. Dudding is Honorary Secretary of the Institute, and Honorary Secretary of the International Commission on Glass. He and the late Sir Clifford Paterson were the first two members of the staff of the Research Laboratories of the General Electric Company Ltd.*]

[In his introductory remarks Dr. Dudding stated that he had never held a post carrying major executive responsibility although he had been the leader of groups engaged on research. His comments were based on about forty years' experience as a research worker involving frequent contacts with chief executives, works' technical staffs and operatives of all grades as well as with scientific colleagues within and without industry. Owing to the exigencies associated with two world wars that experience had not been gained wholly in the diverse industries within his own organisation but also with other industrial concerns both large and small.]

" It is helpful to think of modern industry as a complex organism involving a trinity of activities which can be classified conveniently under the headings craftsmanship, human relations and applied science. These are not independent factors but are found in all concerted efforts of men. The results of group efforts are manifest in the material benefits provided and in the degree of personal satisfaction members of the group derive from participation in the joint effort. Material benefits cannot wholly replace those mental and spiritual values which are summed up in ' personal satisfaction.' I think there is no doubt whatever that the quality of the service provided by research workers associated with an industry depends more on the quality of these activities within the industry than on the scientific attainments of the worker."

" There are some industries which have existed for ages and in the following of which man has found means of expressing himself, and in which he has collectively and individually gained a high degree of skill and knowledge by long experience leavened by flashes of genius. These industries are characterised by the fact that they are based on the use of materials found in and on the earth. On the other hand, there are many industries which have arisen directly out of scientific discoveries and whose initiation largely depended on having the guidance of scientifically trained men. Among this group are many branches of the chemical industry, the electrical industry and its rapidly developing offspring often referred to as the electronic industry."

" In the industries based on long established practice more difficulties have generally arisen. These difficulties have been of two kinds. Those engaged in them were, and often still are, skilled craftsmen whose techniques have been developed as the result of generations of experience and consequently they have great confidence in their power to provide all that is necessary to the well being of their industry and tend to be unsympathetic, if not hostile, to intruders. While this has certainly been an obstacle to the application of scientific methods to old industries perhaps even greater difficulties have arisen from the characteristics of the raw materials and the nature of the processes used in these industries. They are extremely complex, demanding—for even a reasonable understanding of them—a large amount of detailed investigation. These scientific enquiries had of necessity to be undertaken in the early stages by persons having little personal skill and experience in the associated crafts. Each of the two groups of persons concerned, therefore, found it extremely hard to sympathise with the attitude of mind of the other and sympathy is a necessary condition for happy collaboration. These difficulties still retard the application of science in the smaller units of this class of industry."

" Figures have been published in England which show that a very high proportion of industry is carried out in organisa-

tions employing less than 500 people, but I do not know how far this is true in other industrial countries. This suggests thinking of industrial research associated with small and large organisations. Human relationships have always played a major part in the development of these ancient industries and have also determined the degree of satisfaction and pleasure which those engaged in them have enjoyed."

"In small industrial groups the personality and the ideals of the leader have played and still play a dominant role, and many small organisations owe their competitive capacity in relation to larger ones to the inspiration derived from fundamentally sound leadership. It is more difficult for admirable qualities of leaders of large organisations to diffuse without distortion throughout the organisation. Much industrial unhappiness and lack of success are due to weaknesses of the human spirit which are such that the undesirable characteristics of leaders appear to be more readily acquired and transmitted throughout an organisation than the more desirable qualities."

"Small industrial groups often depend largely on craftsmen untrained in the scientific mode of thought and, in my experience, rarely include among their workers even one man with a broad training in science allied to the industrial processes used. One excuse frequently urged by those responsible for not engaging a man trained in the scientific mode of thought is that he is too expensive. A proposal to raise a bank loan involving an interest payment comparable with the salary commitment would be given much more competent scrutiny and generally be more readily entertained, yet the probability of the cost being met by improved efficiency would not be higher than the probability that the cost of the addition to the production team of a scientist under suitable conditions might be recovered by a reduction in waste material and effort, or by the advantages derived from attention being directed earlier than it otherwise would have been to new knowledge. To lose business to a competitor is not necessarily the most efficient way of having attention directed to new knowledge."

"The small organisation without scientifically trained men also forfeits the possibility of utilising the information placed at its disposal by a research or development organisation maintained jointly by subscriptions from governmental and industrial sources. Such institutions may not be common on the Continent but over forty now exist in England, and the criticism of their utility by those operating small concerns often arises from the fact that having been rash enough to make an annual subscription to a joint research organisation, amounting to rather less than the wage of a junior clerk, they fail to obtain any benefit from the investment. This is because they have not provided the channel by which information can be transmitted to them. Scientific and technical knowledge cannot be turned to industrial use by the writing of reports, but only through the channel of human intercourse under conditions of mutual respect and understanding."

"Even when trained men are engaged in small or large organisations sufficient thought is not always given to the creation of conditions which would be favourable to the efficient use of their training. One of the errors most frequently made is to take no steps to encourage the scientist to consort with others of similar training engaged in other branches of industry. Business executives adopt many procedures, some of them particularly agreeable, by which they can meet and exchange views with men of like training, responsibility and experience. They do so not only for the information they glean but also for the mental stimulus provided by such contacts. Yet not infrequently a young scientist is constrained to live on the intellectual capital accumulated during his brief training and given little opportunity or encouragement to broaden his knowedge or to seek the stimulus provided by joining in discussions with others. It is obvious that this is of major importance where only one or two scientifically trained men are associated with an industrial organisation. Sometimes encouragement to participate in outside activities is given but its effect largely negatived by undue restriction on the publication by the scientist of characteristics of his work having general scientific interest. No professional man likes to participate regularly in the work of a scientific society if he is debarred from being a contributor."

"The creation of research and development laboratories within large organisations can be considered to be in the experimental stage. Various types of organisation have been adopted, differing not only in the internal organisation of the laboratory, but also in the arrangements made to govern the relationships of the laboratory with the manufacturing units, sales organisations and the chief executive body. Sir Clifford Paterson, in referring (in 1947) to the objects we had in view in 1919 when the laboratories of the General Electric Co. Ltd. began to function, stated that there had never been a strong difference of opinion about them throughout a period of nearly thirty years. They were :—

'(*a*) The first and most important is to give scientific service to the factories and departments of the Company.

(*b*) Secondly, from the intimate experience so gained with these factories and departments to draw inspiration to formulate and carry out such longer-term researches as in the opinion of the laboratory staff will ultimately benefit their industry.

(*c*) Thirdly, to join in any outside activities in which an industrial scientific staff can help the professional life of the community'."

"When creating a research laboratory (as distinct from a works control laboratory) it is desirable that its chief should not be made responsible to the manager of the works which the laboratory is expected to serve. Where this has been done the research organisation becomes absorbed largely with the works' difficulties, many of which are really the concern of the technical supervisory staff of the works and well within their ability to handle, particularly if they freely consult their research colleagues. If the chief of the research laboratory is responsible to the chief executive of the parent organisation then it is unwise for the executive to instruct works' managers to seek help and guidance from the laboratories. It is better that the laboratory staff should be expected to win the confidence of the works' management."

"There has been much discussion on whether so called pure research and applied research or development should be carried on together. One reason, and the principal one, for not doing so is that those doing pure research are completely protected from the distractions associated with development work. In practice this can also mean that they are also isolated from valuable sources of inspiration. The danger of isolation leading to some degree of stagnation is real, except for very rare and outstanding men, and the organisation is indeed blessed if it possesses more than one such man in each of the phases of science on which its work impinges."

"The advantage derived from mixing the different types of work is that real research problems arise out of difficulties encountered in applying what is already known. Industrial development is dynamic, not static, and there is always a need

to increase the store of specialised knowledge associated with a particular project. Further, well conceived development plans frequently disclose new fields of investigation of primary importance to the long term interests of the project."

"Some argue that academic research lies wholly in the province of the university but this cannot be sustained except possibly in the cases of the smallest research organisations. Of course, the nature of such academic research is generally related to the needs of industry, but it helps to bring industrial research workers in closer contact with university people than they would be otherwise. Another way of achieving and enhancing this purpose is by arranging for university men of high standing to visit the research laboratory regularly for the purpose of discussing with the members of the staff matters on which the university man is an acknowledged authority. It is also advantageous to carry on the two types of research in intimacy because thereby those engaged on applied research enjoy daily contact with specialists and are helped and stimulated. Like all men, research workers vary in temperament and it is often desirable that a good, as distinct from an outstanding, academic research worker be given the opportunity and the satisfaction of carrying some of his work to an advanced stage of development. To see a long term of work reach practical achievement can give to some men immense pleasure, and serve to stimulate new mental activity. Arrangements to this end can be made without entirely divorcing the worker from academic research if the development facilities are close at hand."

"I conclude by offering some comments on the training of men for the type of industrial research which does not lie wholly in the academic field. A large number of inter-acting factors are involved which it may be useful to refer to without detailed comment.

(i) 'Research' has become a term of industrial respectability and thus increased the demand for trained men which has tended to outstrip the supply. This effect has been exaggerated by the war and has had some influence on the quality of the men available. Attempts to meet this by hasty expansion of university facilities may aggravate rather than alleviate the trouble.

(ii) The arrangements made by industry have not been consistently of such a character that university professors have been encouraged to recommend good men to seek careers in industry.

(iii) The large growth of government controlled laboratories with a high degree of employment carrying an assured pension has considerable attraction for the less courageous and adventurously minded students of science.

(iv) In some of the older industrial countries there may still linger a shadow of the old tradition that industry is hardly a fit occupation for persons having a long professional ancestry."

"A somewhat unwholesome mixture of the foregoing appears to manifest itself in another way and place obstacles in the way of students obtaining some of the experience which would help to fit them for industrial posts. Students of physics and chemistry willingly seek for and accept vacation employment, with or without a small payment, in established industrial laboratories but few of them undertake duties in the manufacturing side of industry, a practice which has been followed by engineering students for more than half a century. By doing so the student learns something of the behaviour, speech and mode of thought of industrial troops and their non-commissioned officers and will have little opportunity to develop undue conceit in the importance of his training. American students accept all kinds of vacation employment and it may be that this makes some contribution to the undoubted success with which American industry absorbs new discoveries and at the same time maintains high productive efficiency. A research scientist will do much to assure the failure of his work if, during his contact with persons in the manufacturing unit, he creates the impression of attaching too great importance to his training or of attributing too little value to their experience."

"It is my opinion, and one gaining more general acceptance in England, that factors of the kind referred to have retarded the growth of scientific method in industry because not enough first-class men who have enjoyed the privilege of a broad scientific training find employment and satisfaction in the strenuous and adventurous atmosphere of a manufacturing industry."

## NOTICES TO MEMBERS

### Bournemouth Convention

There has been a good response from members to the invitation to attend the Bournemouth Convention and the number whose ladies are attending is specially gratifying. A limited number of additional applications could still be accepted although only the more expensive hotel accommodation (thirty-five shillings or more a day) is available. All places on the technical visits are filled.

### Salary Enquiry

The Board has approved the making of a further survey of salaries and emoluments received by members. The survey will relate to salaries received on June 1, 1953, and enquiry cards will be circulated shortly. As with the previous surveys, the information supplied will be treated in strict confidence and will be known only to the Institute's two senior permanent officers, Dr. H. R. Lang and Mr. N. Clarke. It will be divulged by them only in statistical form ; a report will be published in the *Bulletin* in the early autumn. The Board hopes that all members will support the survey so that, as on previous occasions, the results will clearly be representative of the whole membership.

### List of Members

It is nearly five years since the last list of Institute members was published ; a new edition along similar lines to the last is now being prepared. Members' names, qualifications, appointments and private addresses will be included and these personal details will be sent to every member during the next few weeks in order that the proposed entry concerning him may be approved.

The list, which will run to some 250 pages, should be ready for publication in the late summer or early autumn. Copies will be available to members free on request.

### Monographs for Students

The publication by the Institute of a series of monographs suitable for students of physics in technical colleges and universities has been under consideration for some time. The series has now been launched by the publication on May 15 of the first four volumes. These are *Soft Magnetic Materials Used in Industry*, by A. E. de Barr, F.Inst.P., *The Magnetic Circuit*, by A. E. de Barr, F.Inst.P., *Fundamentals of Thermometry*, by J. A. Hall, F.Inst.P., and *Practical Thermometry*, by

J. A. Hall, F.Inst.P. The price of each volume is 5s. to non-members ; members of all grades may purchase one copy of each volume at the special price of 3s. 6d.

The subjects and style of these books have been carefully selected so as to fill a real need. The authors are eminent in their special fields and have wide knowledge of industrial applications ; the monographs are intended for students in degree courses in physics and engineering and in the various Higher National Certificate courses and also for the teachers of such students.

### Institute Publications

A complete catalogue of the current and forthcoming Institute publications has now been produced and a copy is being sent to every member. Attention is particularly drawn to the special rates available to members ; these, of course, are made possible only by the contribution to initial production and overhead charges which members make through their subscriptions and by the wide sale of books and journals at the full retail prices. These sales, as the figures in the April *Bulletin* showed, produced over £20,500 in 1952 and the gross receipts from journal advertisements amounted to a further £5,500 ; both these figures should be increased in 1953. The surplus from the publishing activities is used for the launching of new books and for the financing of non-professional work such as education and the holding of conferences.

### Summer Meetings

Arrangements have now been made for three summer meetings of which details could not be included in the half-yearly booklet of meetings. Members of the Branches and Group concerned will be notified individually of the detailed arrangements.

*London and Home Counties Branch.*— The summer meeting will be held on June 27 and will take the form of a visit to the College of Aeronautics at Cranfield. Transport by coach from London has been arranged.

*Yorkshire Branch.*—The Summer Meeting has been arranged for July 11 when a visit will be made to Cooke, Troughton & Sims Ltd., at York. The Meeting will open with a lecture by Mr. E. W. Taylor, F.Inst.P., on " Recent Advances in the Industrial Use of the Microscope," and this will be followed by demonstrations.

*Education Group.*—The summer meeting will be held on June 20 and will consist of a visit to the Physics Laboratories of the University of Reading. A special program will be arranged for members' ladies.

As usual members' ladies and (as far as numbers permit) other guests will be welcome at these visits which are intended to have social as well as scientific interest. These summer meetings are among the most successful of all Branch and Group activities and younger members in particular are most welcome.

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## RESEARCH ASSOCIATIONS

## I — THE ELECTRICAL RESEARCH ASSOCIATION

By S. WHITEHEAD, M.A., D.Sc., M.I.E.E., F.Inst.P.

### CO-OPERATIVE RESEARCH

A research association cannot be dissociated either from the movement as a whole or from the industry it serves. The idea of co-operative industrial research, sponsored by the Government, took shape in the 1914-1918 war and its effective application began in 1920. Two principles were then stated, firstly, that the work of research associations would primarily interest concerns unable to afford private research and, secondly, that government help was temporary. Neither principle persisted.

Fig. 1 shows the financial history of the movement. After ten years the national importance of the general efficiency of each industry favoured permanent government grants. The remarkable way in which the movement weathered the depression of the 1930's showed its strength. Since then its steady growth has led to the present level of some forty research associations with a total income over £3.6 million. So far nationalization has caused the disappearance only of the Gas Research Board. No research depends wholly on nationalized industries and it is thought, even should such a circumstance arise, that an autonomous research association would be desirable in the national interest. The present Department of Scientific and Industrial Research policy is to provide incentive grants, depending on industrial contributions, during growth, and a fixed grant when established at a suitable level.

After allowing for the large proportion of British industry which is carried on by small firms, these appear no readier to support research associations than large firms. Indeed, co-operative research results are much more quickly applied by concerns with suitable technical staff. The nature of the industry is more important than the size of the units.

The three industries most dependent on scientific research are the chemical, electrical and scientific instrument industries.

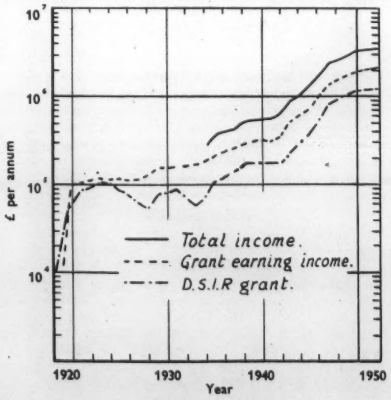


*Fig. 1. Financial development of the Research Association movement*

The chemical industry has no research association (although a Chemical Engineering Committee has been formed by the D.S.I.R.); instrument makers have always found the cost of development high compared with their capital and income, so that the Scientific Instrument Research Association is an obvious solution; the electrical industry needs a more detailed description.

### THE ELECTRICAL INDUSTRY

The industry is highly organized in technical matters. For academic research twenty universities or constituent colleges have electrical engineering departments and 31 have physics departments : 125 technical colleges are recognised by The Institution of Electrical Engineers and several carry out research of a high standard. Apart from societies such as The Institute of Physics, concerned with basic sciences, The Institution of Electrical Engineers fosters and co-ordinates a great deal of research by its scholarships and fellowships and through its committees on Codes of Practice and Regulations. The British Standards Institution has a similar influence. Trade associations, such as the British Electrical and Allied Manufacturers' Association, the Cable Makers' Association, the Electric Lamp Manufacturers' Association and the Radio Industry Council, co-ordinate a large volume of technical work by their members. Many government departments pursue electrical research, such as the National Physical Laboratory, Radio Research Organization, the Post Office and the Ministry of Fuel and Power. The great electrical work of the defence ministries finds its way to industry in a considerable degree.

Many ask what need has the industry of research associations. The short answer is that none of the preceding bodies has primarily the duty of co-operative research for the whole industry. Its needs are too extensive and complicated and research is often so expensive that neither can the needs be adapted to a patchwork of facilities nor safeguarded by overlapping research. Accordingly the industry supports to a greater or less degree many research associations besides the E.R.A., such as the Cast Iron, Ceramics, Coal Tar, Coal Utilization, Cotton, Export Trade, Glass, Hydromechanics, Internal Combusion Engine, Iron and Steel, Linen, Motor, Non-Ferrous Metals, Paint, Paper and Board, Parsons' and Marine Engineering Turbine, Production Engineering, Rayon, Rubber, Scientific Instruments and Welding research associations.

### HISTORY OF THE E.R.A.

Both the Institution of Electrical Engineers Research Committee (1913) and the British Electrical and Allied Manufacturers' Association Research Committee (1915) organized researches. In 1917 they united to form the Electrical Research Committee and E. B. Wedmore (a Founder Fellow of The Institute of Physics) was appointed its chief executive officer. The Committee was incorporated as the E.R.A. in 1920 and its subsequent financial history is shown in Fig. 2. Supply undertakings were admitted to full membership in 1929 and the supply industry has remained the principal contributing group. The British Electricity Authority and Area Boards provide about one-third of the total income on agreements of about 3 years' duration. The membership comprises, in fact, the whole of the electricity supply industry in the British Isles, a large proportion in the Commonwealth overseas, 80% by size of contribution of the manufacturing industry (excluding that of radio sets and the tele-communication industry as such), overseas manufacturers, The Institution of Electrical Engineers, large users as the Transport Commission, suppliers of insulating materials, boiler makers, tube makers and, mainly indirectly, steel makers. Apart from the D.S.I.R., the Ministries of Fuel and Power, Agriculture and Fisheries, Supply and the Admiralty make special contributions up to about 10% of the total income. With an income of considerably over a quarter of a million pounds the E.R.A. is one of the four largest research associations.

At first the Association's research work was mainly carried out extramurally at the National Physical Laboratory, universities and members' laboratories. Work by the staff was confined to switchgear, owing to the then Director's leading position in that field, and to individual researches in temporary stations or at universities. A great deal of extra-mural work continues, about £30,000 p.a., as before, but in 1935 H.R.H. the late Duke of Kent opened the E.R.A. Laboratory at Perivale, which soon became its main establishment. The Field Station at Shinfield was established at the end of the late war and also the office and publishing departments were moved to Leatherhead, leaving only a small London office in

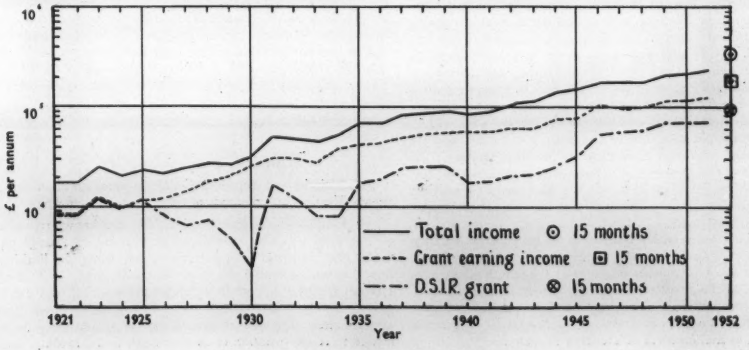


*Fig. 2. Financial history of the E.R.A.*

the Institution of Electrical Engineers' building. The staff has grown to about 300, with 60–70 graduates or equivalent. The Perivale site of 1¾ acres became too congested so that 50 acres was acquired at Leatherhead to rehouse the research work and it is hoped shortly to start building.

Since the work initially was largely extra-mural and co-ordination was of prime importance, the E.R.A. developed an elaborate committee system on the lines of the British Standards Institution and The Institution of Electrical Engineers, since it was giving similar services in the research field. This system, with some simplification, has persisted, although most of the work is done by the staff, for the chief reason that it is impossible to make contact individually with all the relevant technical staff of members in so scientific an industry as the electrical industry. Although a great deal is achieved by the Information Bureau, Technical Liaison and research visits, yet the main contact with the senior technical staff responsible for putting the Association's discoveries into practice is made through the 1,000 members of the technical committees.

The E.R.A.'s income is only some 5% of the amount spent by the industry in private research and development research. Accordingly its programme has to be concentrated on the most advantageous and important of those topics which would not be provided for otherwise. Inspiration cannot be commanded, it must be pursued when and where it arises, but the E.R.A. does not seriously enter a new field without consultation with the members who may be affected. This consideration may aid the understanding of the main types of work, described and illustrated in the rest of this article.

### TYPES OF RESEARCH

*Development research.*

This comprises studies aimed at fairly practical discoveries which will influence design, operation and development. Since development costs many times more than research a successful study of this kind will stimulate or aid a very great volume of development by members. The switchgear research is an outstanding example. When the E.R.A. started its work oil immersion of circuit breaker contacts was usual for power station breakers. Photographs taken with E. B. Wedmore's high speed camera showed that the tips of the arcing electrodes were still within a bubble of gas when the arc went out. It was found that the arc could be extinguished in hydrogen though not quite so easily as in an oil circuit breaker except with additional cooling. As cooling was improved the arc shortened. With hydrogen or air under pressure allowed to escape through the top contact the arc length was reduced to about a tenth. The shorter the arc the less the energy released and the more easily could the blast carry away the hot ionised products so that the arc went out at the current zero. Thus was the principle established of keeping the arc as short as possible and providing arrangements for imprisoning it on the up-stream side within the high velocity region of the escaping blast. The oil in a switch is also useful for cooling if close to the arc path. This and other features are embodied in the side blast baffle switch which imprisons the arc and oil in a small enclosure with a number of lateral passages starting close to the arc path to allow rapid escape of hydrogen and oil vapour across a number of points in the length of the arc. These and ancillary discoveries form the basis of most modern high-power switchgear. The arc control pots, definitely based on the E.R.A.'s patents and now in commercial use, aggregate 1½ thousand million kVA of breaking capacity.

Protection against surges, particularly lightning, is a compromise between cost and the probability of the hazard. This has led to a long and difficult research on the distribution of faults, the relation between faults and thunderstorm activity, the likelihood of a stroke to earth in a thunderstorm, the distribution of lightning currents and effects of design on the chance of neighbouring strokes.

Among the major possible improvements in insulation, reduction of volume and elimination of service failures are promising. E.R.A. investigations show that breakdown in service is complicated, is not directly related to true electric strength and includes at least one, sometimes all, of the following secondary factors : erosion by gaseous discharges ; stress concentration at the end of discharge channels ; thermal instability due to energy losses ; electrochemical attack by products of electrolysis due to leakage currents ; ordinary chemical changes due to oxygen, nitric acid, ozone and heat. The E.R.A. is studying all these aspects and methods are being found for controlling them. For example, one electrochemical change, due to liberation of hydrogen by leakage current, can be blocked by adding small quantities of hydrogen-accepting substances. The life of capacitors with chlorinated impregnants has in this way been prolonged five to thirty-fold. (Fig. 3). The main factor in breakdown of high voltage insulation is attack by the ions of gaseous discharges at the edges of electrodes or within voids and interstices. This action is particularly destructive at high frequencies on account of the great number of discharges per second. When high voltage high frequency cables first came into use it was found that the 50 c/s strength of the cable bore no relation to its life at radio frequencies. The discrepancy resulted from discharges in minute voids between conductor and dielectric, and the correct voltage rating of such cables was determined from observation of the inception voltage for discharge. No failures occurred at the ratings so determined.

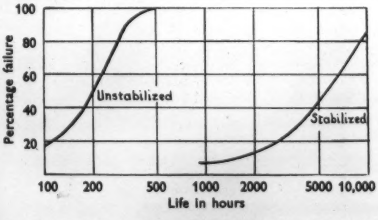


*Fig.* 3. *Effect of stabilization on life of chlornaphthalene impregnated paper capacitors at 70°C.*

*Research for basic information.*

This includes the improvement of practice, common data, standardization and methods of test.

(a) *Improvement of common practice.* The best known research of this type was the determination of standard ratings for cables and overhead lines involving, first, fixing the limiting temperatures tolerable by the materials used, and then estimation of the manner in which heat is absorbed and transmitted by the surroundings. The first great step was the establishment of standard ratings for the steady state, with factors to cover variation of environment, cyclic loading, and short-time peak loads. Extension to take account in greater

detail of daily loading cycles is now in preparation. Short-circuit ratings also are an obvious extension : these bring into play new factors of mechanical strength.

The National Physical Laboratory has, during nearly 30 years, amassed for the E.R.A. a unique record of the electrical properties of every important dielectric over the widest practicable ranges of humidity, temperature and frequency, extending into the centimetric region. More recently analogous work with impulse voltages has provided sound limits of dielectric stress, since insulation design at high voltages is largely conditioned by the impulse test.

(b) *Common Data.* Tables of the thermodynamic properties of steam are essential to the designer and operator of steam turbines by which nearly all the electric power in this country is generated. The subject is also a part of pure science, and therefore suitable for a university. The work began under Professor Callendar, whose fame rests in part on the tables which bear his name, and continued under Sir Alfred Egerton and Professor Newitt. The present stage is the extension to 1,400°F and 6,000 lb./sq. in. pressure.

Knowledge of the restriking voltage of the network is necessary for circuit-breaker design so that the E.R.A. has surveyed its nature for all the circuit-breaker positions of the British Electricity Authority 66 kV system and is engaged on the 132 kV system.

For many years the E.R.A. has collaborated with the Safety in Mines Research Board (now Safety in Mines Research Establishment, Ministry of Fuel and Power) to provide data for the design of and some testing facilities for flameproof electrical gear in which Great Britain leads the world. The electrical work on incendivity combines well with that on ignition systems in spite of the apparent diversity of problems such as plug sparkover voltages.

The E.R.A.'s survey of wind-power for the selection of sites where the wind régime is sufficiently favourable for development covers the whole of the British Isles. Data have also been collected from many parts of the world.

(c) *Standardization.* Standardization is eminently the way by which a great deal of co-operative research influences industrial practice.

The E.R.A. inherited the problem of insulating materials which were then usually of poor and variable properties. In the course of years it has defined, shown how to measure and given appropriate values for all the important features of insulation including permittivity, loss angle, electric strength, corona resistance, tracking resistance, electrical and thermal resistivities, tensile strength, cross-breaking strength, impact strength, tearability, grindability, machinability, creep, relaxation, plastic yield, inflammability, ignitability, heat resistance, chemical stability, moisture resistance and permeability, conducting inclusions, pinholes, compatibility of insulants. Specifications for components, such as capacitors, depend largely on properties of insulating materials.

The British Standard for light lines, derived from E.R.A. designs, has had a considerable influence on economical rural electrification. The group of radio interference specifications owes very much to the E.R.A. in reducing to workable terms a subject of extreme technical difficulty.

(d) *Methods of Measurement and Test.* Most of the apparatus and methods of test for insulating materials, including oils, have arisen from or in connection with E.R.A. work. They are too numerous and well known for separate mention except for two recent field instruments to test for incipient breakdown

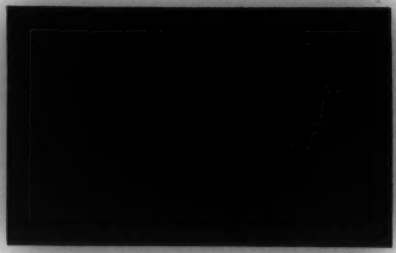

*Fig. 4. Recording of discharge current pulse, using sealed-off cathode-ray oscillograph, with time base of* $2 \times 10^{-8}$ *sec. The lower trace is a timing oscillation* 100 *Mc/s.*

—a simple dispersion meter for moisture and an a.c. discharge detector. The E.R.A. has developed the use of the sealed-off cathode ray oscillograph for high speed recording up to the limit imposed by the physical dimensions of the circuits studied (Fig. 4). An economic type of network analyser suitable for steady state, harmonic and transient solutions of networks, is to be enlarged to cover the whole probable range of practical problems which can be represented by systems of linear equations. A compact radio-interference measuring set has been adopted by the Admiralty, who are allowing its civilian use.

(e) *Long-Term Development.* Two examples illustrate projects on which an individual concern would be unlikely to take the sole risk of recovering later its preliminary effort.

Examination of the bulk transmission of power across water or desert or for long distances overland has shown the potential importance of d.c. at high voltages and a plan to use a cable across the Channel is under consideration. The problems of how a system can be started, controlled, protected against faults, and how to design the terminal equipment to avoid undesirable characteristics have been tackled successfully on the model scale, leading to the invention of refined methods of control.

The use of wind-power might save an appreciable amount of coal if there are enough sites with appropriate wind régimes and if efficient and reliable generators can be supplied within a certain cost. The wind surveys and analyses already mentioned have answered the first question in the affirmative and provided quick and cheap methods of site selection. The second problem is being attacked by a co-operative group comprising the supply authorities, plant manufacturers, the Ministry of Fuel and Power, with aid in research and co-ordination from the E.R.A.

(f) *Co-operation with Other Industries.* Progress in turbine efficiency is largely conditioned by the availability of steels suitable for high temperatures and pressures. Long term stability is an important feature which the creep tests and corrosion studies for the E.R.A., in co-operation with British Iron and Steel Research Association, at the National Physical Laboratory have covered with great advantage.

(g) *Co-ordination within the Electrical Industry.* In telephone interference the interests concerned are electricity supply, the Post Office, electric traction and also plant manufacturers who have to meet specifications. They meet and put in hand investigations under the E.R.A.'s ægis.

In radio interference the public is also involved and the Association has taken part in the quantitative assessment of the reaction of listeners and viewers. The Association's impartial role has been extensively exploited by the Postmaster-General's advisory committees set up under the 1949 Wireless Telegraphy Act and by the international committee on radio interference.

(h) *Consumer Problems.* The best known work is that on consumer security, particularly protective earthing and fire risks. Research is difficult because a very high standard of safety has been reached and the very small risks arise from rare combinations of extreme circumstances.

The main object of the work on rural electrification is to investigate applications of electricity to agriculture and horticulture, using equipment and operating techniques which at the same time will be effective and economic for the farmer as well as providing satisfactory loads for the supply authority. In particular, low electric loading is aimed at both to reduce the capital cost of the equipment and to improve its load factor. The work is equally of value to the agricultural industry and the Ministry of Agriculture and Fisheries has, during the last few years, borne half the cost of most of the researches. The investigations include the drying of crops, the design of barn and field machinery, dairy sterilising, electrical methods in poultry husbandry, general instrumentation, pest destruction, the effects of electric shock on animals and fish, electric space heating and soil warming, artificial illumination in horticulture. For any one research organization, unaided, to undertake such a range would mean a prohibitive cost. For example, researches on flash illumination and air conditioning is using 1,000 laying hens. By working in collaboration with the Reading University poultry department the E.R.A. is relieved of any responsibility for providing or maintaining the hens.

Work on heating problems is directed towards the most efficient and convenient use of electricity. Floor-heating has been explored, both in the laboratory and field, for thermal storage and because the large radiating surface permits lower air temperatures; high air temperatures are costly and less comfortable. Novel forms of heat storage are being studied. Electricity is also well adapted to transient heating and the E.R.A. has shown the great reduction in time to attain comfort if high resistivity or reflecting wall coverings are used. The heat-pump has also been studied and developed for increasing the total efficiency of electrically-run heating. A full-scale working plant is in use at the Shinfield Field Station (Fig. 5).

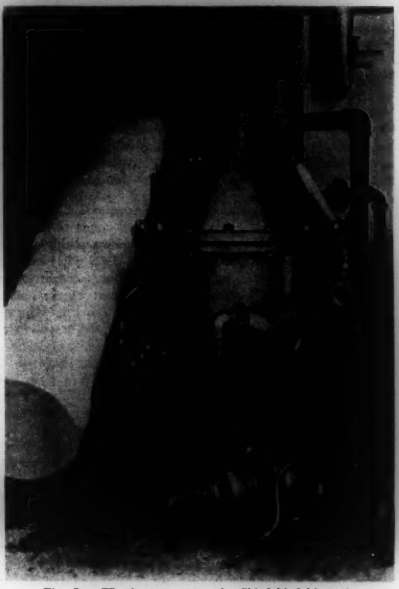

*Fig. 5. The heat pump at the Shinfield field station.*

### *Fundamental Research*

This is one of the main duties of a research association and a substantial portion of the resources is so allotted. The greatest effort and the greatest successes have concerned materials.

Early work on dielectric breakdown revealed the handicap that there was no basic theory of the electrical instability of solids and liquids. With the help of Professor Mott a team was assembled comprising theoretical physicists under Professor Fröhlich and (mainly) experimenters on the E.R.A. staff. As a result the theory of the solid state was extended to cover electrons in solids and a quantitative theory of electronic breakdown was developed which gave, mainly without disposable constants, an agreement with experiment within experimental dispersion. Although this so-called intrinsic electric strength has an application to impulse strength, the main importance of the achievement was that breakdown could now be classified as electronic, thermal, discharge, or electrochemical and the last three could be pursued with improved technique to yield direct applications to industrial problems, which has been done with considerable success.

The extensive work on magnetic materials has found its way into the Institute's own publications and so will not here be repeated.

An important group of basic researches deals with discharge phenomena fundamental to the switchgear arc, the welding arc, the useful and dangerous explosive sparks, the flashover discharge, internal and external dielectric discharges, lightning and possibly, according to Dr. Bruce, cosmical phenomena.

### *Speculative Researches.*

These are researches so unpromising in practical outcome that only a central body will take a chance on them. The direct conversion of electrochemical into electrical energy offers great rewards in fuel efficiency, unlimited storage, light weight and low cost. Practical difficulties have denied success hitherto but the E.R.A. selected one method for small scale study. The progress was encouraging, and although there are still difficulties there are still reasonable hopes.

### CONCLUSIONS

A few examples, out of many, have been chosen in the foregoing for rapidity of exposition. They will, it is hoped, lead to the conclusion that research associations, a British invention, have an important and individual part to play in industry. It is further hoped that the conclusion will be drawn that this is true of the E.R.A. in spite of the great technical resources and success of its industry to which it claims to have made some contribution.

# PHYSICS IN TECHNICAL COLLEGES

## III — THE COLLEGE OF TECHNOLOGY, BIRMINGHAM

By M. R. GAVIN, M.B.E., D.Sc., F.Inst.P.

There was a time, not long ago, when the physics department of a technical college was looked on as a service department whose main function was to make good the deficiencies in the school education of the part time student, before he proceeded to his "real" technical study in some branch of engineering. To-day in most large colleges the physics department holds a high position in its own right. Courses with physics as the main subject are considered by industrialists to form a sound training for many of the scientists needed in industrial laboratories. The marked increase in the use of branches of applied physics as legitimate subjects for college instruction has led to wider interests and enhanced reputation. In many cases the colleges are building up research groups in branches of applied physics.

During the past few years the Physics Department of the College of Technology, Birmingham, has been taking part in these general developments. Before giving some details of the present position some brief historical notes may be of interest.

The College opened shortly before the close of last century. The first Principal, Dr. W. E. Sumpner, was also head of a combined Electrical Engineering, Physics and Mathematics department. A fair proportion of the investigational work in connection with the Sumpner alternating current instruments was done in the laboratories and workshop of the Department. Later a separate Electrical Engineering department was established but the Principal continued as head of the Physics and Mathematics department until his retirement. At the start, when the main load was evening work, much of the advanced teaching was done by visiting lecturers but as part-time day work increased the staff was enlarged and more and more of the advanced work was done internally.

With Birmingham University so close, the College and department has always relied mainly on part time students, and full time courses have only been large during post-war periods.

### SOME NUMERICAL DATA

The department is responsible for all the physics and mathematics of the College and also for ophthalmic optics. There is a full time teaching staff of 24, of whom there are 14 physicists, 9 mathematicians and one optician. The staff categories are 8 senior lecturers, 8 lecturers, 3 assistant lecturers and 4 research assistants. There are also 2 mechanics, 4 laboratory technicians and one clerical assistant. Arrangements are being made for an additional mechanic and a glass blower.

Most of the teaching is concerned with post-graduate, degree or higher national certificate courses. There are a few ordinary national certificate and intermediate science classes, but it has been College policy to reduce the elementary work wherever possible.

The numbers of students in the various physics courses during the present session are given in the table. The numbers in most of the categories have been increasing steadily during the past few years. The figures do not include the large number of students who take physics as an ancillary part of another course.

It will be seen that the majority of the students in the department are industry-based, i.e., they are part time students who are engaged in the laboratories of a wide variety of industries. There are students from all types of engineering —heavy and light, mechanical, electrical and civil—and from metal, glass, rubber and plastics industries. Many of the full time students also have a connection with industry. Some have changed from part time to full time classes in order to complete their degree courses. In some cases these students are financed fully by their firms for a period of one or two years of full time study, at the conclusion of which they return to the firms.

*Table of Numbers of Students, Session* 1952–53

| | *Numbers of Students* | |
|---|---|---|
| | *Full time* | *Part time* |
| B.Sc. (Special Physics) ... ... | 5 | 10 |
| B.Sc. (General Science) ... ... | 25 | 93 |
| National Certificate in Applied Physics | — | 48 |
| Post-graduate ... ... ... ... | — | 100 |
| Ophthalmic Optics ... ... ... | — | 25 |

### ACCOMMODATION AND EQUIPMENT

As in most colleges shortage of laboratory accommodation is a constant problem. There are five teaching laboratories, two advanced, one elementary, and two for applied physics. There are in addition two small research rooms and an optics room. The introduction of applied physics and research makes large demands on space. Much of the equipment is necessarily bulky and must be permanently set up. One of the laboratories for applied physics contains two 100 kV X-ray sets for radiography, an X-ray diffraction unit (Fig. 1), a spectograph and some vacuum equipment. The second applied laboratory is used mainly for electronics (Fig. 2). Here the equipment, being fairly portable, may be stored in cupboards when not in use, so that the laboratory may be used for other purposes. The remaining laboratories are in almost continuous use and on most days three different sets of experiments are set out.

*Fig.* 1. *X-ray diffraction unit.*

The laboratory equipment covers a fair range of the conventional experiments in pure physics up to the Special

*Fig. 2. Electronics laboratory.*

Physics standard. New experiments are being added regularly. Some of the equipment for applied physics has already been mentioned. In electronics there is a good variety of apparatus for valve and circuit experiments covering the range from low frequencies to microwaves.

The first research room was improvised from a " tunnel " underneath a tiered lecture room (Fig. 3). Research workers for this room have to be selected in accordance with their physical dimensions as well as their academic ability ! Passage from one end of the room to the other is facilitated by a sideways stoop. Even so, some effective work has been done in this room. A second research room has been provided by partitioning-off a portion of a preparation room (Fig. 4)

***Fig. 3.*** *Research room underneath a lecture room. Note the sloping ceiling.*

Perhaps the most valuable space in the department is the workshop. Here there is a good selection of metal and woodworking equipment and a small glass lathe. An additional precision lathe and a miller are being added.

Another room is fitted out as a teaching workshop for glass blowing and mechanical optics. General workshop practice for the physics students is obtained in the Production Engineering Department of the College.

COURSES

The principal courses in physics are for the external degrees of the University of London in General Science and Special Physics, and for the Ordinary and Higher National Certificates in Applied Physics. Additional courses for the Graduateship examination of the Institute are being organized for holders of pass General degrees and Higher National Certificates.

Some attempt has been made to encourage part time students to take the applied physics course as being more appropriate than the external degree for the industry-based student. This policy has met with only limited success as both students and firms still attach great value to a degree. However, the development of the applied physics has had its influence on the other courses and more and more " applied " experiments are being introduced into the degree courses.

At the same time it should be emphasized that the treatment of the applied physics with the national certificate students

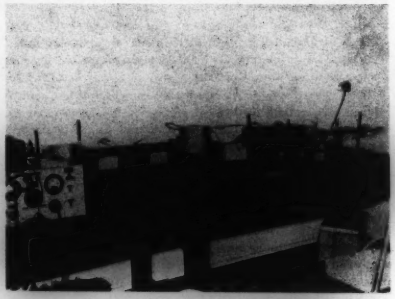

*Fig. 4. Microwave equipment for research work on insulators.*

is directed towards the inculcation of basic physical principles and not towards the training of technicians. Electronics is used as a subject to illustrate and teach basic principles of electrostatics and electrict circuit theory ; vacuum technique is an extension of the kinetic theory of gases, and so on. The objective is to teach principles first and foremost ; technique may be acquired incidentally. The main branches of applied physics which are being covered are electronics, X-ray technology, spectroscopy and vacuum technique.

Several post-graduate classes have been run during the past few sessions for graduates or holders of higher national certificates. Some of the subjects covered are electronics, X-ray technology, gamma-radiography, photo-cells and microscopy ; and on the mathematical side, Laplace transforms, non-linear differential equations and vector analysis. Additional courses planned for the future include physics of solids, electromagnetic waves, numerical methods, and matrices and tensors.

RESEARCH

The importance of some research in advanced educational establishments has been emphasized frequently. In spite of the serious problems of accommodation and equipment some effort has been made to develop original work within the Department. The College Governing Body has shown great interest in these developments and has helped considerably by the creation of the new type of staff appointment called

the Research Assistant. These people are appointed to the normal teaching staff as Grade A assistants but their teaching is limited so that most of their time is available for research. There are at present four Research Assistants in the Physics Department and most of their teaching time consists of laboratory demonstration. In addition to the Research Assistants eleven members of the staff are doing some kind of original work. Five members of staff, including the Research Assistants, are reading for higher degrees ; one has already been awarded. Research colloquia are held at regular intervals.

The main field of research is high frequency electronics. Some of the projects under investigation are (a) factors affecting the performance of ultra-high-frequency triodes ; (b) electron transit time oscillations in triodes ; (c) equivalent circuits of semi-conductors ; (d) physical properties of insulators at high frequencies and high temperatures ; (e) rubber model and electrolytic tank methods for potential distributions ; (f) survey of conformal transformation methods for electronic devices and (g) mathematical problems of interplanetary travel. Some of the electronic work is financed by an Admiralty research contract. The research on u.h.f. triodes was made possible by the gift of a range of special valves from the Research Laboratories of the General Electric Company Ltd. The Department has also received gifts of equipment for the research program from the Dunlop Rubber Company Ltd. and the M-O Valve Company Ltd.

No great claims are made for the achievements of the Department in the research field. However, there is no doubt that there is an enthusiastic team getting a great deal of pleasure from its research work and it is hoped that the Department is gaining a similar measure of benefit from the teaching point of view.

## REVIEWS OF BOOKS

**Studies in Conservation.** The Journal of the International Institute for the Conservation of Museum Objects, Vol. 1, No. 1, October, 1952. (London : Thomas Nelson & Sons, Ltd.) Price 21s. each number.

In introducing a new journal something should be said to justify an addition to the ever growing list now confronting any scientist. For *Studies in Conservation* it may at the outset be claimed that it is the only journal covering specifically the application of science to the study of archæological objects and works of art, for which there has been no medium since *Technical Studies in the Field of the Fine Arts* ceased to appear in 1942.

Apart from its specialist appeal, *Studies in Conservation* is likely to be of more than marginal interest to scientists in general ; this is because the objects dealt with will, in addition to their historical or æsthetic qualities, reflect the scientific knowledge of their period in the materials used and in the technique. The first number, for example, contains a contribution from Mme A. R. Wiell, A.Inst.P., which is in effect an X-ray diffraction study of equilibrium in a Au-Ag-Cu alloy "annealed at room temperature" for 40,000 years. The object examined, by non-destructive methods naturally, was a piece of Egyptian jewellery and it is shown that two phases exist where the equilibrium diagram indicates a single solid solution. It is also shown that the effect of cold work in the region of the drilled holes is still to be observed in the back reflection patterns. Another article, by R. D. Buck, deals also with the effect of long periods of time on the properties of a material. He has measured over a cycle of relative humidities, the moisture content of twelve samples of wood ranging in age from one year to 3700 years and found the decrease in hygroscopicity, if it exists at all, to be very slight. The dimensional stability of an old piece of wood is therefore no greater than one of recent origin ; both are equally subject to the radial-tangential section factor. The remaining paper by P. Coremans, J. Thyssen and R. J. Gettens, is based on a very thorough scientific examination of a notable painting and is an excellent example of what micro-chemical analysis, radiography, and so on, may reveal about the materials and methods used in a work executed between 1464 and 1468.

Finally, it will interest readers of the *Bulletin* to know that the editor is F. I. G. Rawlins, F.Inst.P., who has the assistance of an international advisory Committee which includes Prof. E. A. Owen, F.Inst.P.

S. Rees Jones.

**Introduction to Physical Chemistry.** By A. Findlay. 3rd edition revised by H. W. Melville. (London : Longmans, Green and Co.). Pp. vii + 592. Price 28s.

Professor Melville has made several changes in the new edition of this well-known text-book without altering its general character, which is that of an elementary introduction requiring no advanced mathematical knowledge on the part of the reader. The most important changes are that the chapters on chemical change, catalysis, absorption and the colloidal state have been very extensively overhauled, brought up to date and arranged among the other chapters in a more logical sequence. Professor Melville has wisely decided not to include discussions of wave-mechanics and the theory of valency, subjects which are frequently classed as physical chemistry but which are probably better dealt with under the heading of general or structural chemistry and which in any case would be out of place in a book of this character.

Perhaps the most obvious shortcomings of earlier editions were a tendency to carelessness about units and dimensions and a somewhat slipshod treatment of some of the thermodynamics. These criticisms do not apply to the new chapters which Professor Melville has written but his revision of the older chapters has not gone far enough. Thus we still read that R (the gas constant) "obviously has the dimensions of work," and physico-chemical quantities are sometimes quoted without units and occasionally with wrong units (e.g., calories instead of calories per mole) ; the frequent use of the word "numbers" for "figures" in referring to tabulated data which are certainly not pure numbers is also unfortunate.

Students trying to obtain some of the elementary results of thermodynamics in mathematical form often go astray because the possible number of variables is greater than they have been used to elsewhere, so that they do not appreciate the fundamental importance of distinguishing clearly between dependent and independent variables and between complete and incomplete differentials. Unfortunately, although they may have had a good grounding in elementary calculus, many of them will not have encountered partial differentiation by the time they start their physical chemistry, so that the path of the writer on elementary thermodynamics who wishes to be simple yet precise is hard. Nevertheless Professor Findlay is not as meticulous as he should be in this matter, and on occasion his lack of logical definition may perplex the conscientious student and deceive others.

These criticisms aside, the book is a sound introduction to classical and modern physical chemistry and should be widely popular for elementary university work ; it is well produced and misprints and errors are rare. By comparison with other modern text-books the price is by no means unreasonable, although remembering that this is an elementary book which will probably not retain a permanent place on the bookshelves of many of its owners one cannot help wondering whether the production of an alternative edition in stout paper covers at a much lower price (as in the case of Professor Findlays' *Phase Rule*) would not have been justified here. E. G. Cox.

**Mysticism and Logic.** By BERTRAND RUSSELL. (London : Penguin Books Ltd.) Pp. 220. Price 2s. 6d.

It is not easy to review a book of essays written some forty to fifty years ago and last revised only a little more recently. A critique of Russell's early work is hardly possible in the space available : all that can be attempted is to try to assess the value of this re-print to a modern reader.

The book falls naturally into two parts. The first is a popular exposition and is easy to read. The most striking feature is the emphasis on paradox, sometimes to the point of contradiction. Thus Russell finds the most perfect freedom in the service of a self-created God ; yet in the same year he sees, in the discovery that our minds are capable of dealing with material not created by them, one of our best means of overcoming our human weakness. Likewise his emphasis on cognition, almost to the exclusion of conative and affective activities, so strongly emphasized in some sections, would appear to be denied in others.

The later chapters of the book require really careful reading—always with an eye on the date of writing (unfortunately only to be found in the Preface). Yet it is remarkable how well much of this work has stood the test of time. In a few cases, one is pulled up sharply by a phrase such as " the natures of infinity, of continuity, of space, time and motion—are now no longer in any degree open to doubt or discussion," written in 1901 and surprisingly not amended in 1917. But in most cases, Russell has the prophetic gift of forseeing what is the main building and what will prove, as he puts it, to be scaffolding. This is strikingly true of his postulate of non-data sensibilia which he clearly regarded at the time as a very temporary structure.

His theories of perception are badly " dated " now that we have read the controversies between the Gestalt psychologists and their opponents, not to mention the so called " New Look " synthesis ; all of which has proved an admirable incentive to experiment.

Finally, the reader cannot but be impressed with the lyrical style, sometimes unconsciously turning to blank verse, which occasionally breaks through the heavier philosophical writings (though this is in the earlier sections). " Some must keep alive the sacred fire : some must preserve in every generation, the haunting vision . . . which shadows forth the goal of so much striving."

To-day, we do not need so urgently to be warned against the dangers of belief in social progress as did our fathers, but the physicist is still inclined to extrapolate too widely such generalizations as the laws of thermodynamics. Much of Russell's writing is directed against too wide a generalization of what may prove to be local developments. This salutary aim alone would justify the study of his work by a new generation of physicists. G. W. SCOTT BLAIR.

**Science and Religion.** By CHARLES E. RAVEN, D.D., D.Sc., F.B.A. (Cambridge : The University Press). Pp. 224. Price 21s.

This volume contains the first series of the 1951 Gifford Lectures on " Natural Religion and Christian Theology," the second series of which, *Experience and Interpretation*, is to be published in the autumn of this year. It is a remarkable work; there are few to-day who are equipped to attempt an intellectual feat of this order and there are even fewer whom one would expect to achieve the degree of success which Dr. Raven has reached. Yet it is a somewhat disappointing book ; it is erudite, scholarly, in parts vigorous and stimulating, but, often lacking the sense of persuasiveness which many of us have come to expect in Dr. Raven's work.

Dr. Raven proclaims " the continuity of nature and supernature." His book is a history of science into which an account of the varying climate of theological thought has been delicately woven so as to produce a history of the degree to which the sacred and the secular have been held to be antithetic. It is essentially, and, I think, rightly for this purpose, a history of the biological sciences. Dr. Raven asserts that " nothing is more evident than that the era of modern science . . . in its early stages . . . owed far more to the biologists than to the mathematicians, far more to the anotomists and herbalists, the gardeners and explorers than to the astronomers. To represent the history of science, as is done in all the text-books, as a papal succession, Copernicus, Kepler, Galileo, Newton with Boyle and Hooke and a few others wedged into the series, is only possible on the assumption that the important contributions are those which led up to the dominant mechanism and determinism of the late nineteenth century. Historians of science have, until recently, committed the same error as historians of the early Church in the fourth and fifth centuries : they have written as if the only events of importance in the previous period were those which directly anticipated and promoted the current orthodoxy of their own day."

The historical narrative begins with a chapter on the Biblical attitude towards nature. From the Jewish outlook—the love of nature but also the view that " the world is God's world, shaped by His wisdom and obeying His law . . . but it is also a place of darkness and cruel habitation in which the righteous does not always flourish and his seed seems sometimes to be forsaken "—we reach that of Jesus who teaches " by bidding men consider the lilies and the birds, by setting a child in their midst, by telling tales of sowers and fishermen. . . . The background of His discourse is nature not supernature and He aims not at turning our eyes and minds away from the natural order but at enabling us to discover in it and through it the manifestation of deity." Paul and the writer of the Fourth Gospel saw, as did the early Church, that " an integrated and harmonious exposition of the universe was a necessary part of any Christian theology " but by the beginning of the dark ages " faith became a creed, hope an escapism and love a snare ; to contrast the transient with the supernatural, to flee from the world rather than to convert it, and to order this life so as to secure the bliss of heaven became the object of Christian endeavour."

Thus to the middle ages when " neither Franciscans nor Dominicans succeeded in establishing a serious regard for the study of nature within the Church," rendering " inevitable the upheavals and revolts of the Renaissance and Reformation," and on to the sixteenth and seventeenth centuries (still with

Dr. Raven's insistence on the vital importance of biological rather than physical thought) to the period of the founding of the Royal Society, and to the gradual creation of " the picture of the world of nature as a self-contained mechanical system, capable of being interpreted mathematically in terms of the motion of matter in space and time." " Newton himself was constant in affirming the presence, energy and control of God as the ground and cause of all that is. But his followers, enthusiastic over the completeness of his demonstration . . . naturally regarded it as a vindication of a mechanistic outlook: and this was accentuated in the next century by the lack of worthy representatives of the biological sciences or of religion."

With the industrial revolution and the cutting off of urban communities from " contact with the rhythm of nature, the slow processes of agriculture," came " at first a deistic and then a virtually atheistic outlook . . . a concept of faith in purely intellectual terms and an insistence that since all knowledge is based upon experience and ultimately upon sensation the field of knowledge is small, speculation is to be discouraged and tolerance to be advocated." The increasing dominance of physics and chemistry in the eighteenth century " went far towards destroying all consciousness of the wholeness of nature and of the integrative life of the organism. Split up into systems respiratory, digestive, reproductive and the like, man became a thing of shreds and patches to be taken to pieces like the wheels and screws and spring of a watch, cleaned up and put together in better shape for keeping time." So, through the nineteenth century, to the new situation created by modern physical theories and the work of modern theologians.

There will not be universal acceptance of Dr. Raven's evaluation of the significance, for his purpose, of all the evidence, scientific and theological, which he quotes but it is unlikely that anyone could fail to recognise his seeking of objectivity. This is a book which ought to be very widely read and should certainly be read by physicists. It is a pity that Dr. Raven did not make the task a little easier in places. He often quotes references which, at any rate to the non-specialist, seem to add nothing except weariness to the reader ; particularly is this so in respect of the innumerable footnotes. It is to be hoped that such a procedure will be avoided in the second volume so that Dr. Raven's vigorous style can show itself unimpeded.

NORMAN CLARKE.

**Contributions of Science to Peace.** (Alex Wood Memorial Lecture 1953). By CHARLES A. COULSON, F.R.S. (London : Fellowship of Reconciliation). Pp. Price 1s. 6d.

Those of us who teach or engage in fundamental research in science, and especially in physics, find ourselves facing a dilemma. This dilemma is not merely that our work may be used for evil as well as for good, but that we are in the dangerous position either of having to justify our continuance in that work in spite of the fact that it places dangerous tools in the hands of unscrupulous, weak and foolish men, in which case we may tend to retire into a self-assumed state of isolation from political and social responsibility ; or of being looked up to as something only a little lower than gods, in which case we may be tempted to accept the homage and pontificate on subjects about which we know very little.

In this year's Alex Wood Memorial Lecture, Professor Coulson glances at and indeed underlines these obvious dangers, but refuses to allow them to weigh too heavily by comparison with the enormous potentialities of science, if rightly used, in promoting human welfare. He predicts the use of nuclear transformations for the economic generation of power within twenty years, and gives astronomical figures for the possible horsepower that could be developed from tides, wind, water and sun, if only the lethargy that inhibits almost all development except that intended for military purposes could be dispelled. He believes that the contribution of science to peace can be made not so much by refusal to do certain things as by dedication to the performance of others. The spring of that dedication he finds in religion. No doubt he is right, but the need for brevity has made it sound a little too simple. Perhaps he could enlarge on his theme in a more detailed exposition ?

KATHLEEN LONSDALE.

## THE REGISTER

ELECTIONS TO MEMBERSHIP

An asterisk (*) indicates transfer from another grade.

*Fellows*

Cole, Horace, B.A., Deputy Chief of Research, Pilkington Bros. Ltd., St. Helens.

*Evans, Ivor, M.Sc., Senior Scientific Officer, Ministry of Supply.

Houldin, Joseph Eric, B.Eng., Ph.D., Senior Lecturer in Physics, College of Technology, Birmingham.

Oosterkamp, Wybe Johannes, Dr. Tech. Sc., Senior Physicist, Philips Research Laboratories, Eindhoven.

*Runcorn, Stanley Keith, M.A., Ph.D., Assistant Director of Research in Geophysics, University of Cambridge.

*Vodden, Cyril Charles, M.Sc., Radio Valve Development Engineer, Edison Swan Electric Co. Ltd., Enfield, Middx.

*Associates*

*Brown, James Graham, B.Sc., A.R.C.S., Technical Officer (Physicist), I.C.I. Ltd., Dyestuffs Division.

*Buchan, Ronald Charles Thomas, B.Sc., Assistant Physicist, S.W. Regional Hospital Board Cancer Organization.

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*Buteux, Richard Harold Barclay, M.Sc., Assistant Technical Officer, I.C.I. Ltd., Plastics Division.

Carrington, Herbert Edgar, B.Sc., Lecturer in Physics, College of Technology, Leeds.

Chappell, Frank Arthur, B.Sc., Research Physicist, L. Oertling Ltd.

Clarence, Noel Desmond, M.Sc., M.A., Lecturer in Physics, University of Natal, Durban, South Africa.

Clarkson, Montague Ernest, B.Sc., A.R.C.S., Technical Officer, I.C.I. Ltd., Dyestuffs Division.

Cox, Sidney Walter Reginald, B.Sc., Senior Scientific Officer, National Institute of Agricultural Engineering, Silsoe, Beds.

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*Dorman, Richard George, B.Sc., A.R.C.S., D.I.C., Experimental Officer, Chemical Defence Experimental Establishment, Porton Down, Wilts.

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Jones, Timothy Douglas, B.Sc., Senior Physics Master, County Grammar School, Llandyssul, Cards.

*Leak, George Matthew, B.Sc., Ph.D., Deputy Head of Metallurgy Division Laboratory, British Iron and Steel Research Association, Sheffield.

MacKelvie, John Stewart, M.A., Assistant Physicist, St. Bartholomews Hospital, London.

Marshall, Donald George, B.Sc., Ph.D., Senior Research Physicist, Dunlop Rubber Co. Ltd., Birmingham.

Mason, William Muir Templeton, B.Sc., M.A., Secretary, N.E. Scotland Co-ordinating Committee for Certificates in Technology. Secretary, Aberdeen and N.E. Regional Advisory Council for Technical Education.

*Matthews, William Douglas, B.Sc., Research Student, King's College, London.

*Mee, Charles Denis, B.Sc., Ph.D., Research Physicist, Steel Co. of Wales (Lysaght Division), Newport.

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Morris, David Alwyn, B.Sc., Assistant Lecturer in Physics, Technical College, Crumlin.

*Mortlock, Allan John, M.Sc., Research Officer, C.S.I.R.O., Melbourne, Australia.

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Sharp, George Edward, B.Sc., Assistant Lecturer in Physics, Royal Technical College, Salford.

Simms, Dennis Lionel, B.Sc., Scientific Officer, Fire Research Station, Borehamwood, Herts.

*Sumner, Fred, B.Sc., Refinery Physicist, Shell Refinery and Marketing Co. Ltd., Chester.

Wilson, Cyril George, M.Sc., Senior Lecturer, Military College of Science, Shrivenham, Wilts.

*Wrist, Peter Ellis, M.Sc., M.A., Research Physicist, Quebec North Shore Paper Co., Canada.

Wylie, Russell George, M.Sc., Ph.D., Research Officer, C.S.I.R.O., Sydney, Australia.

*Graduates*

*Adams, Henry Stewart, B.Sc., Officer Cadet, R.A.F. (National Service).

Bevan, Gwyn Arthur James, B.A., Physicist, Richard Thomas & Baldwins Ltd., Kidderminster.

*Brimfield, Elwyn George, B.Sc., Department of Education, University College, Swansea.

Brown, William James, B.Sc., R.A.F. (National Service).

*Buswell, Albert Geoffrey, B.Sc., Technical Officer, I.C.I. Ltd., Dyestuffs Division.

Carter, Derek George, B.Sc., Student, Education Department, University of Bristol.

*Coleman, Colin Roy, B.Sc., Technical Assistant, Bristol Aeroplane Co. Ltd., Bristol.

*Compston, William, B.Sc., Geophysicist, Bureau of Mineral Resources, Australia.

Cripps, Alan Derek Harold, B.Sc., Assistant Lecturer in Physics, Woolwich Polytechnic.

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*Dixon, Norman Edward, B.Sc., A.R.C.S., Physicist, E.M.I. Research Laboratories, Hayes.

Docker, Ian Robertson Wyatt, B.Sc., Senior Demonstrator in Electrical Engineering, University of Melbourne, Australia.

*Freemantle, Reuben George, B.Sc., Research Student, University of Birmingham.

Gooberman, George Lancelot, B.Sc., Graduate Apprentice, Marconi's Wireless Telegraph Co. Ltd., Chelmsford.

Hately, Gordon Fisher, B.Sc., Post-Graduate Apprentice, A. Reyrolle & Co. Ltd., Durham.

Holbeche, Thomas Anthony, B.Sc., Research Student, University of Birmingham.

Houseman, David Henry, M.A., University Research Worker, Department of Metallurgy, University of Cambridge.

Hyde, Geoffrey Robert, B.Sc., Research Assistant, British Nylon Spinners Ltd., Pontypool.

*Kehoe, Richard Brian, B.Sc., A.R.C.S., Research Student, Imperial College, London.

*Kennedy, Peter John, B.A., Demonstrator, King's College, London.

*Kent, Thomas Brian, B.Sc., Technical Assiatant, Ministry of Supply, Capenhurst.

*Kenyon, Peter Arthur, B.Sc., Research Student, University of Manchester.

Kirkman, John Roy, B.Sc., Research Student, University of Durham.

Lewis, Arthur Beesley, B.Sc., Research Student, University College of Wales, Aberystwyth.

*Makepeace, Frederick James Londsale, B.Sc., Pilot Officer, Technical Signals Branch, R.A.F.

*Miles, Howard Thomas, B.Sc., Research Student, University College, Swansea.

*Muff, Peter, B.Sc., Research Engineer, E.M.I. Research Laboratories, Hayes.

Mundkur, Ramdas Santappa, M.Sc., Junior Radio Engineer, Ferguson Radio Corporation.

Mycroft, George Herbert, B.Sc., Graduate Apprentice, British Thomson-Houston Co. Ltd., Rugby.

Myint, Maung Kyaw, B.Sc., Postgraduate Student, Imperial College, London.

*Parkman, Norman, B.Sc., Research Physicist, Electrical Research Association, Perivale.

Plant, Robert David, B.Sc., Assistant Experimental Officer, Ministry of Supply, Capenhurst.

Purslow, Brian William, B.Sc., Ph.D., A.R.C.S., D.I.C., Lecturer in Physics, University of Malaya.

Richards, William John Breese, B.Sc., Research Physicist, Tootal Broadhurst Lee Co. Ltd., Manchester.

Roberts, Ernest Henry, B.Sc., Experimental Officer, Building Research Station, Garston, Herts.

Roberts-Wray, Christopher Waring, B.A., Visiting Fellow, University of Princeton, New Jersey, U.S.A.

*Rosenbaum, Stanley Daniel, B.Sc., Marconi's Wireless Telegraph Co. Ltd., Essex.

*Rowbotham, John Rex, B.Sc., Research Student, University of Durham.

*Saunders, Roy Anthony, B.Sc., Junior Design Engineer, Murphy Radio Ltd., Welwyn Garden City, Herts.

Smith, Michael John, B.Sc., A.R.C.S., Research Physicist, E.M.I. Research Laboratories, Hayes.

Spragg, Robert Claude, B.Sc., Assistant Research Instrument Engineer, Imperial Smelting Corporation.

Symes, William Sydney, B.Sc., Research Assistant, British Nylon Spinners Ltd., Pontypool.

Thomas, William Roy, B.Sc., Physicist, Monsanto Chemicals Ltd., Newport.

Wheeler, Raymond Trevor, B.A., Physicist, British Thomson-Houston Co. Ltd., Research Laboratory, Rugby.

Wilson, Herbert Rees, B.Sc., Ph.D., Research Fellow, University of Wales (working at King's College, London).

Wood, William, B.Sc., Lieutenant, Instruction Branch, Royal Navy, Lee-on-Solent.

*Students*

Barnard, Anthony Charles Langrish, University of Birmingham.

Branch, Victor Frederick, South East London Technical College, Lewisham.

Coker, Raymond, University College, London.
Duggan, Thomas Cecil, University of Birmingham.
Goldsmith, Barry Sanders, University College, London.
Hajjarizadeh, Hossein Ali, University of Birmingham.
Hale, Kenneth Frank, The Polytechnic, Regent Street, London.
Hall, Eric Walter, University of Birmingham.
Haywood, Brian Charles, University of Birmingham.
Hitchings, Derek William, University of Bristol.
Hookway, Brian Robert, Borough Polytechnic, London.
Kirton, Malcolm, College of Technology, Art and Commerce,
Lawes, John, University of Bristol. [Oxford.
Lloyd, William Wallace, Northern Polytechnic, London.
Matthews, Ian Gordon, University of Reading.
McFarlane, Allan Farquharson, University of Glasgow.
Orr, Inez Agnes Peat, University of Glasgow.
Pendred, Keith John, College of Technology, Birmingham.
Price, Maurice Ronald, University of Birmingham.
Rishi, Susheel Kumar, Northampton Polytechnic, London,
Roberts, David Coulter, The Polytechic, Regent Street. London.
Ruben, Julius Thomas, University of Reading.
Rycott, Peter David Dudley, The Polytechnic, Regent Street, London.
Smith, Frederick Arthur, College of Technology and Commerce, Oxford.
Smith, John Connal, University of Glasgow.
Stakemire, Terence John, South East London Technical College, Lewisham.
Sutton, Brian Watson, University of Reading.
Trotman, Robert Edward, The County Technical College, Guildford.
Turner, John Hinwood, University of Reading.
Wilkinson, Robert Phillip, The Technical College, Gloucester.
Williams, Paul Randall, Loughborough College.
Wright, John Layland, King's College, London.

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## APPOINTMENTS VACANT

**The inclusion of particulars of a vacancy must not be taken to imply that the Institute necessarily approves of the terms offered or that might be offered. Candidates should satisfy themselves that these are satisfactory, and they may always refer to the Institute for advice.**

**The University of Liverpool** invite applications for the post of **Lecturer** in Experimental Physics, at an initial salary within the range £550–£900 per annum, according to qualifications and experience.

Applications stating age, academic qualifications and experience, together with the names of three referees, should be received not later than May, 30 1953, by the Registrar, from whom further particulars of the conditions of appointment may be obtained.

**British Electricity Authority** require a **Third Assistant Engineer,** Communications Technical Department. Duties in connection with construction, testing and maintenance of Authority's private communications system, including equipment using line, teleprinter, and radio techniques. Previous experience of this work essential and experience in telephone manufacturer's works valuable additional qualification. Preference given to applicants having university degree with first or second class honours in engineering or physics. Salary and conditions in accordance with N.J.B. Agreement, Schedule C within Class AX, Grade 5 Salary = £681 9s. 0d. to £829 10s. 0d., rising to ultimate maximum £927 3s. 0d. p.a. Applications may be made on form obtainable from Divisional Secretary, B.E.A. London Division, Generating House, Gt. Portland Street, W.1, and be received by May 24, 1953.

**National Coal Board** invite applications for superannuable appointments of **Scientists** at the Central Research Establishments, Stoke Orchard, Near Cheltenham, Glos., to undertake investigations on both laboratory and pilot plant scales into novel methods of separating coal from associated minerals.

Candidates should be physicists, physical chemists or electrical engineers, with at least second class honours degrees or equivalent, and be interested in the physics and chemistry of surfaces. Acquaintance with the technique of handling high voltage light, unidirectional currents and electrostatic charge measurement would be an advantage.

Appointments, according to qualifications and experience, will be as Scientist Grade I (salary scale/range £1,095 × £35 to £1,305 to £1,495 per annum) ; Scientist Grade II (Salary £645 × £30 to £1,095 per annum ; or Scientist Grade III (salary £445 × £25 to £845 per annum).

Write giving full particulars (in chronological order) of age, education, qualifications and experience (with dates) to National Coal Board, Central Research Establishment, Stoke Orchard, Near Cheltenham, Glos., marking envelope TT/624. Closing date May 26, 1953. Original testimonials should *not* be forwarded.

**The British Iron and Steel Research Association** require a **Physicist** for the post of Head of the Physics Department, the work of which includes fundamental and applied research into the physics of the processes, equipment and products of the iron and steel industry.

Candidates should have an Honours degree in physics, and experience in the direction and administration of research either industrial or academic.

Starting salary from £1,360 per annum upwards according to age, qualifications and experience. Post is superannuated under the F.S.S.U. Location of work London. Written applications only to Personnel Officer, B.I.S.R.A., 11 Park Lane, London, W.1.

**Physicist** with experience in radio-active methods to develop applications of tracer techniques in rubber industry Applications in writing to the Personnel Manager, **Dunlop Rubber Co. Ltd.,** Erdington, Birmingham.

**Physicists** for fundamental research on felt and applied research in the feltmaking industry. Candidates must have at least second-class Honours in physics, applied mathematics or engineering. Experience in the application of statistical methods an advantage. Experience with textiles also an advantage but not essential. Salary in accordance with qualifications and experience. Superannuation under F.S.S.U. Applications to the **British Hat & Allied Feltmakers Research Association,** Stanley House, Manchester Road, Fairfield, Droylsden, Manchester.

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**University of Oxford,** Department of Pharmacology, require an **Electronics engineer,** graduate or non-graduate. If applicant is a graduate he should have some interest in biology. Duties would include maintenance, design and construction of research equipment. Salary according to qualifications. Applications to Professor J. H. Burn.

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Required one **assistant physicist,** aged 20–25, Inter. B.Sc. standard, and preferably with some experience of mechanical and general physical testing of plastics and related compounds. Apply, giving details of age, experience, salary required, to Dr. V. E. Yarsley (Research Laboratories) Ltd., Oaklands, Clayton Road, Hook, Surrey.

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**Institute of Cancer Research,** invite applications from Honours graduates in Physics or in a biological subject for **Studentships** in Biophysics and in Medical Physics tenable at the Physics Department of the Institute of Cancer Research, Royal Cancer Hospital, London, S.W.3. These Studentships will normally be awarded for two years, starting 1st October, 1953, and may lead to the M.Sc. degree in Biophysics of the University of London. The grant would normally be at the rate of £300 per annum.

Application should be made with the names of two referees, to the Secretary, Institute of Cancer Research, Royal Cancer Hospital, London, S.W.3, not later than 30th June, 1953.

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**The British Steel Castings Research Association** invites application for the following staff vacancy in its Sheffield laboratories :—**Physicist** of graduate or equivalent standing for work involving the application of physical methods to dust problems and to metallurgical research. Successful applicant would be required initially to undertake experimental research into methods of monitoring and measuring airborne dust, and later to proceed to a wider field of study. Experience of microscopy and the use of radioactive materials would be an advantage.

Successful applicant will be expected to work with the minimum of supervision, and must be accustomed to report writing and to the presentation of experimental data. The appointment carries the status of Scientific Officer, is permanent and superannuable. The salary envisaged is within the approximate range £600–£900, dependent on qualifications.

Applications, which will be treated in confidence, should be in writing to : The Director, British Steel Castings Research Association, Broomgrove Lodge, Sheffield 10.

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**College of Technology, Birmingham,** Department of Physics and Mathematics. A **Senior Lecturer** in Physics is required for September, 1953. The Department is concerned mainly with work of degree and post-graduate standard. Experience in some branch of applied physics such as X-ray technology, vacuum technique, spectroscopy or acoustics is essential. Teaching experience is desirable. There will be suitable opportunities for research.

Salary will be in accordance with the Burnham (Further Education) Scale for Senior Lecturers (Men), £1,040 × £25 — £1,190, (Women) £832 × £20 — £952.

Further particulars and application forms from the Registrar, College of Technology, Birmingham, 1, to whom the completed forms should be returned by May 24, 1953.

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**The Commonwealth Scientific and Industrial Research Organization** invites applications for appointment to a position of **Physicist** to its Biochemistry Unit, Wool Textile Research Laboratories, Parkville, Melbourne, Victoria. Duties : To participate in an intensive program of research on the structure of wool and other fibrous proteins by chemical and physical methods. Qualifications : University Honours degree in science or equivalent qualifications with research experience in the use of X-ray diffraction, preferably as applied to studies of the structure of proteins or high polymers. Salary : Within the range of Research Officer, £A836 to £A1,244 p.a. actual, thirteen increments. Salary includes a cost of living adjustment of £A180 p.a. Fare to Australia (including those of wife and family) will be paid. Appointee may be granted Superannuation privileges.

Applications, referring to Appointment No. 462/51, and stating full name, place and date of birth, nationality, marital state, present employment, particulars of qualifications and experience and of war service, if any, accompanied by names and addresses of at least two persons willing to act as referees, if so required, and copies of not more than four testimonials, should reach the Chief Scientific Liaison Officer, Australia Scientific Liaison Office, Africa House, Kingsway, London, W.C.2, from whom further particulars may be obtained, by the June 26, 1953.

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**Senior Scientific Officers** required by **Division of Atomic Energy (Production)** at Sellafield, Cumberland ; Salwick, near Preston ; Culcheth, near Warrington, to lead research teams in theoretical and experimental work on the following topics : general physics and applied nuclear physics concerned with operation of nuclear reactors and associated processes, including health physics ; physical and inorganic chemistry of metals and compounds used in atomic energy processes, including radio-active materials ; extraction, purification and recovery of metals ; refractory materials ; physical metallurgy of radio-active metals ; melting and casting of metals ; X-ray crystallography of unusual metals and compounds. Qualifications : over 26 with at least 2nd class Honours degree in Chemistry, Physics, or Metallurgy (or equivalent) with 3 years post graduate research experience. Specialized experience in one of fields mentioned desirable. Salary £781–980. F.S.S.U. may be applicable. Good prospects. Houses within reasonable time, if married. Applications to Ministry of Supply, D. At. En. (P), Risley, Warrington, quoting 444.

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**Physicist** (University Graduate), with research and industrial experience, preferably in photography and the graphic arts, is required to join a recently formed team engaged on interesting new projects in important printing organization in London. Knowledge of electronics and ability to converse in French and German would be an advantage. Starting salary £1,200—£1,400 per annum. Permanent pensionable appointment for right man. Applicants should write stating age, qualifications and experience with full details of career in chronological order to Research Manager, Box No. A.V. 38, The Institute of Physics, 47 Belgrave Square, London, S.W.1.

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**Technical Management.** A University Graduate is required for training in Technical Management. Knowledge of mathematics (pure and applied) and physics is essential. Training in engineering is advantageous ; some knowledge of chemistry is desirable. Interest in Works production essential. Apply Box No. A.V. 37, The Institute of Physics, 47 Belgrave Square, London, S.W.1.

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